Zero Till vs Conventional Tillage with Two Rotations: Crop Production over the Last 10 Years

S. A. Brandt
Agriculture Canada
Experimental Farm
Scott, Sask.

Abstract

A study was initiated in 1978 to compare zero-till with conventional tillage crop production in two rotations; fallow-oilseed-wheat and oilseed-wheat-wheat with canola and flax alternating in the oilseed year.

In both rotations, soil moisture levels were higher at seeding time with zero tillage than with conventional tillage. Most of the difference occurred in the 0-15 cm profile of soil where crops were sown on stubble. With the fallow treatment, more moisture was stored throughout the soil profile under zero-till.

Crop yields varied considerably from year to year but when combined over the 10 year they were quite similar for the 2 tillage systems. Generally wheat tended to yield more and the oilseed crops (canola, flax) less under zero than conventional tillage. Where yields of zero till crops were lower than conventional tillage, inadequate weed control was usually the primary cause. Several weed population changes occurred with zero tillage and several of these species proved more difficult and costly to control than those present in the conventional tillage system. The results suggest that the adequacy and cost of weed control is a major factor determining the feasability of zero-till crop production on the Dark Brown Soils of N.W. Saskatchewan

Introduction

Zero tillage (or no-till) is a crop production system where tillage is eliminated except for the soil disturbance caused by specialized seeding equipment. It has been promoted as a soil and moisture conserving practice and has gained some acceptance in Europe and the United States. It has not been widely accepted on the Canadian Prairies.

Soil degradation has been identified as a major threat to the future of crop production in this area; summerfallow and tillage practices are implicated as major contributors to the problem. However, summerfallow has proven to be a very effective means of stabilizing producer incomes, particularly in the drier southern prairies and tillage has provided an economical means of controlling weeds, managing crop residues and preparing a seedbed.

This study was initiated to evaluate zero-till as an alternative to tillage and to evaluate whether the use of such practices would provide the means to reduce or eliminate summerfallow on the Dark Brown soils of N.W. Saskatchewan. The objectives of this study were to evaluate zero-tillage from a productivity and economic viewpoint, to determine some of the effects on weed populations and soil properties and to determine what modifications or adaptations would be required to deal with conditions in this area.

Materials and Methods

In 1978, land that had previously been in a fallow-wheat rotation at the Agriculture Canada, Experimental Farm, Scott, Saskatchewan was prepared for use in a long-term study comparing zero tillage with conventional tillage production practices. The study was located on a mixed Elstow and Shallow Elstow (Scott) Loam soil (Clayton and Ellis, 1952), an Orthic Dark Brown Chernozem.

Two rotations were utilized;a continuously cropped rotation of oilseed- wheat-wheat and; a 3 year fallow rotation of fallow-oilseed-wheat. In both rotations, canola and flax were alternated in the oilseed year to avoid potential disease and weed problems. The study was set up as a split-plot, randomized complete block with four replicates. Rotations were used as main plots with tillage treatments as sub-plots. One pair of plots was used for the continuous rotation and three pairs for the 3 year fallow rotation; one pair for each year of the rotation. The two tillage treatments were applied to the pairs of plots. A plot size of 15 m x 94 m was used. Cultural and tillage treatments were performed with commercial farm equipment. Herbicides were used exclusively for weed control in the zero-tillage cropping system. Normally this involved; use of phenoxy herbicides (2,4-D or MCPA) in late fall or early spring for control of broadleaf winter annuals; use of non-selective herbicides (glyphosate, paraquat; occasionally combined with bromoxynil) for control of weeds immediately prior to seeding; use of the same non-selective herbicides for control of weeds in chemical fallow (in 5 of 10 yr. glyphosate at higher rates was used for spot treatment of perennial weeds on chemical fallow). In the conventional tillage cropping system; tillage with a cultivator equipped with spikes or sweeps was performed on stubble in late fall and early spring tillage was with a cultivator equipped with mounted harrows followed by rod weeding (3 to 10 years) or cultivating (7 of 10 years) just prior to seeding for all cropped treatments. The tillage fallow normally required three operations with a cultivator and mounted harrows plus one or two operations with a cultivator or rod-weeder.

From 1979 to 1981, seeding was done with a Haybuster 1206 double-disc press drill, an offset double disc press drill (Dyck, 1980) was used during 1982 to 1984 and a Versatile Noble 2200 narrow hoe press drill from 1985-1988. Wheat and flax were generally sown in early to mid May and Canola in mid to late May. From 1979 to 1984 all phosphate fertilizer was seed placed and N fertilizer surface broadcast and left on the surface (zero tillage) or incorporated (conventional tillage). From 1985-1988 all fertilizer was placed below the seed using a banding attachment on the hoe drill. The oilseed crops grown on fallow received 30 kg/ha of phosphate annually and all crops grown on stubble received 25 kg/ha of phosphate plus 45 kg/ha of N.

In-crop control of annual grass weeds was achieved by using diclofop-methyl on wheat and flax except for flax grown on chemical fallow in 1986 and 1988, where sethoxydim was used at the rate recommended for annual grass control and at the quackgrass rate respectively. Sethoxydim was used on flax in 1988 to suppress a heavy infestation of<u>Foxtail barley.</u> Bromoxynil or bromoxynil plus MCPA was used for annual broadleaf weed control in wheat and flax crops. Trifluralin, fall applied and incorporated was used for broad spectrum weed control in canola grown on tillage fallow and in the continuously cropped rotation. For zero-till canola in both rotations, diclofop methyl was applied. No suitable broadleaf herbicide was available for in-crop use on canola.

Because of difficulties encountered in accurately counting numbers of weeds present, each species was rated each year using the following rating system:

1 - none present
2 - very low numbers present
3 - low numbers present
4 - moderate numbers - competitive
5 - high numbers - very competitive

Records were kept on dates of crop emergence, emergence as plants/sq.M , and dates of crop maturity.
Grain yields were determined at full ripeness by harvesting a 1.15 m x 94 m area from the centre of each plot using a small plot combine. Remaining grain was harvested using a typical farm combine equipped with straw and chaff spreaders which distributed crop residues uniformly on the plot area. The grain was weighed, its volume weight, weight per 1000 seeds and N concentration (Kjeldahl) determined.
Gravimetric soil moisture determinations were made to a depth of 0.91 m in the spring prior to seeding and again following harvest. Levels of available nitrate N and phosphate were determined (Hamm et al 1970), on soil samples collected just prior to feeze up in late fall.
Crop residue measurements were made in July of 1988 by hand picking all residue larger than 2 cm. on the soil surface from two - 1 sq.M areas from each plot. The residues were then rinsed to remove soil particles, dried and weighed.
Metrological records on precipitation, minimum and maximum air temperatures were made at the Experimental Farm Metrological site. Annual precipitation was calculated on a crop year basis (Sept. 1 of previous year to Aug 31 of current year) as it more closely reflected precipitation available for crop production than when done on a calendar year. Growing season precipitation was calculated as rainfall between May 1 and August 31.

Results and Discussion

I. Precipitation

12 month precipitation during the period 1978-88 was 6% above the long-term average (Table 1). In 8 of the 10 years 12 month precipitation was within +/- 15% of the long-term average, and in 2 year it was more than 20% higher than the long-term average (1984-1985) and 1986-1987). During the 1984-85 season, overwinter precipitation was much above normal and July precipitation was extrmely high in 1986-87.
Growing season(May 1-Aug 31) precipitation was near normal for 9 of 10 years but was much above normal in 1986-87 reflecting the very high precipitation in July 1987.Overwinter precipitation was near normal in 8 of 10 years but was more than 100 mm above normal for 1984-85 and 70 mm below normal in 1987-88. During the 1983-84 growing season,very little rainfall occurred after mid-June and crops experienced severe moisture stress.
Overall,growing conditions were near normal for the area during this 10-yr.period.

II. Soil Moisture

At the time of seeding, soil moisture levels in the continuously cropped rotation were higher for zero tillage than for conventional. (Table 2). Most of the difference occurred in the 0-15 cm. profile of soil. Moisture levels at depths greater than 15 cm. were quite similar for the 2 tillage systems.
In the 3 year fallow rotation, moisture storage on chemical fallow was 21 mm higher than on tillage fallow (Table 3). The increased storage occurred primarily over the second winter and was distributed throughout the 0-90 cm. profile of soil.
Soil moisture levels at seeding of the wheat crop in the 3 year fallow rotation were similar with zero and conventional tillage (Table 2). This observation was somewhat unexpected given the higher moisture levels with other zero till treatments.

Table 1. Precipitation at Scott for 10-twelve Month Periods, 1978-1988.

12 month period	precipitation (mm) overwinter (Sept 1. - Apr. 30)	growing season May 1 - Aug 31)	12 month (Sept 1 - Aug 31)
1978-79	189	221	410
1979-80	135	200	335
1980-81	144	177	321
1981-82	133	237	370
1982-83	195	182	377
1983-84	172	173	345
1984-85	270	178	448
1985-86	130	241	371
1986-87	157	308	465
1987-88	84	247	331
10 yr. avg.	159	217	376
long term (75 yr.)	153	200	353

Where zero till resulted in increased moisture levels, the increase could be attributed to some combination of improved snow trapping and snowmelt infiltration and/or reduced evaporation losses with zero till. Observations made at seeding indicated that less drying of the surface soil occurred where tillage was not done. This trend became more evident over time, once a thatch of crop residue had built up with zero till.

Table 2. Soil Moisture Levels (mm) at Seeding in 2 Rotations with Zero and Conventional Tillage (1978-1988 average)

rotation	soil depth (cm)	tillage system zero	conventional	
continuous crop	0-15	39	33	**
	0-90	186	177	*
3 yr fallow				
- oilseed on fallow	0-15	36	32	*
	0-90	212	191	*
-wheat on stubble	0-15	33	32	
	0-90	176	174	
2 rotation average	0-15	36	32	*
	0-90	191	181	**

* and ** denote significant differences between tillage treatments at P=0.05 and 0.01 resp.

Table 3 Spring Soil Moisture (mm) after Fallow in the 3 yr Fallow Rotation with Zero and Conventional Tillage (1978-88 avgerage)

soil depth (cm)	tillage system zero	conventional
0-15	36	33
15-30	36	33
30-45	38	35
45-60	38	32
60-90	66	60
0-90	214	193

III Weed Populations

It was anticipated that some shifts in weed populations would occur when switching to a zero-tillage production system. Further, it was expected that the major shifts would occur in populations of common species. However, two previously unnoticed species; Narrow- Leafed Hawksbeard and Foxtail Barley increased dramatically with zero till. Populations of Narow-Leafed Hawksbeard increased with zero till in the first year of the study and continued to be a problem therafter (Fig 1). Post harvest applications of 2,4-D or MCPA frequently gave incomplete control as did herbicides used for preseeding and in crop weed control. By constrast, post harvest and seedbed preparation tillage provided complete control of this species.
Foxtail barley was adequately controlled by tillage but with zero till numbers did build up after several years (Fig. 2). After 5 years of zero till the rate of Roundup used for preseeding burnoff of weeds was increased to control this species and numbers were reduced to manageable levels until 1988 when special attention was again required.
Other perennial weeds, grasses like Quackgrass and Bromegrass and broadleafs such as Canada Thistle, Perennial Sow Thistle and Dandelion increased (Fig. 3 & 4) under zero till while remaining absent from the conventional tillage treatments. Since few if any of these perennials were present prior to the start of this study it is likely that infestations resulted from seed moving in or present in the soil. This being the case, it is apparent that post harvest and preseeding tillage has been effective in controlling seedlings or first year plants of these species. Spot treatment of isolated patches of these perennials with Roundup or Lontrel was used on approximately 1% of the zero till area annually.
Populations of some annual weed species such as green foxtail and stinkweed tended to decrease over time with zero till compared to conventional practices (Fig 5 & 6). Wild oat tended to be more abundant (Fig. 7) under zero till while broadleaf annuals other than stinkweed showed a variable response (Fig. 8). Where zero till canola was grown, numbers of broadleaf annuals were quite high in early years of the study but tended to decline over time and the zero till canola crop grown in 1987 was relatively weed free. Trifluralin, one of the most effective herbicides for use on canola could not be used with zero till as it requires soil incorporation.

IV. Crop Production

No clear yield trend emerged favoring one tillage system over the other. When averaged over all years, rotations and crops, zero till yields were approximately 60 kg/ha higher than

Fig.1 NARROW LEAFED HAWKSBEARD

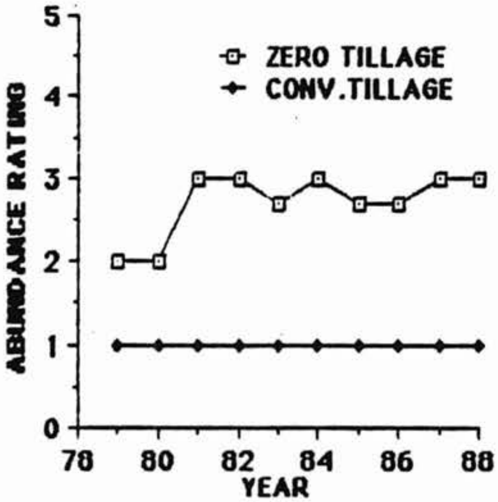

Fig.2 FOXTAIL BARLEY

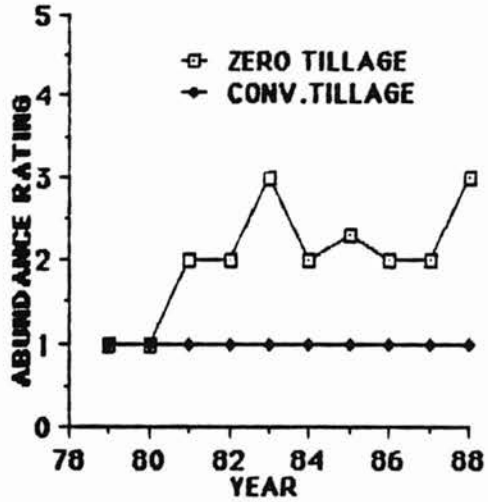

Fig.3 PERENNIAL GRASSES(exc.foxtail bar.)

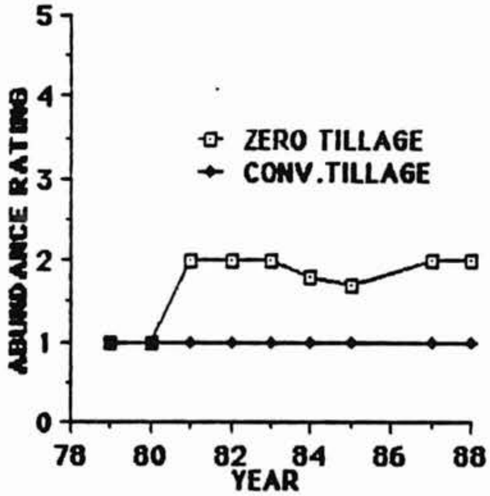

Fig.4 BROADLEAF PERENNIALS

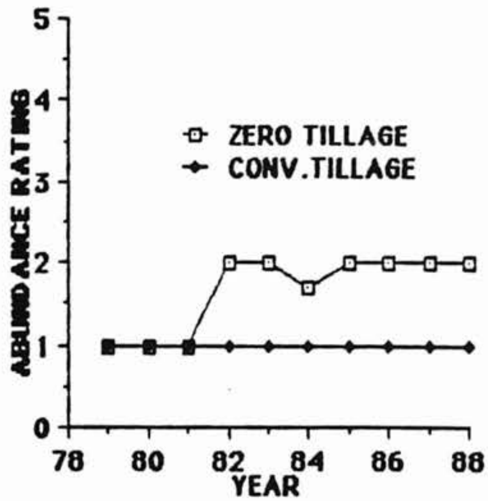

FIGURE 1 TO 4. ABUNDANCE RATINGS FOR SEVERAL WEED SPECIES UNDER ZERO AND CONVENTIONAL TILLAGE CONDITIONS.

Fig.5 GREEN FOXTAIL

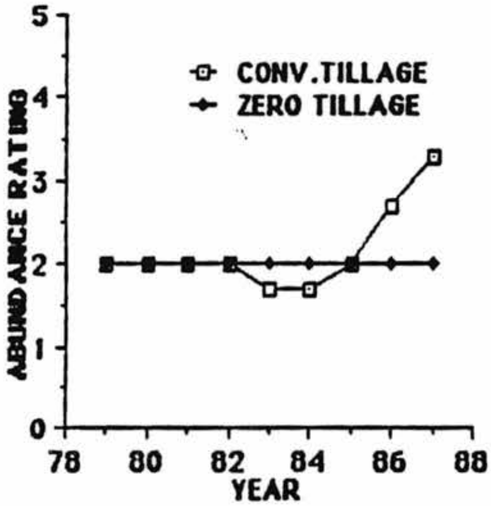

Fig.6 ABUNDANCE OF STINKWEED IN OIL

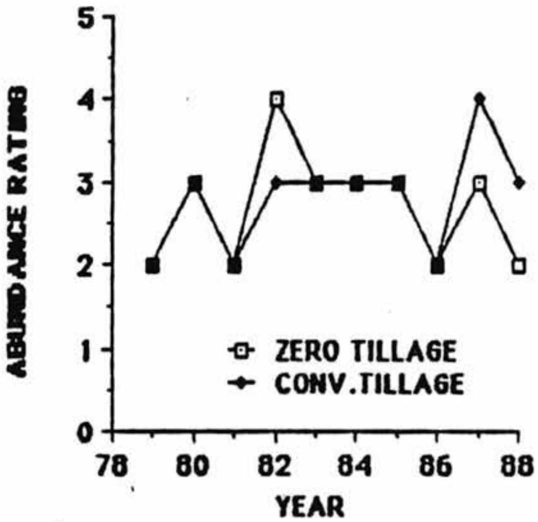

Fig.7 WILD OAT

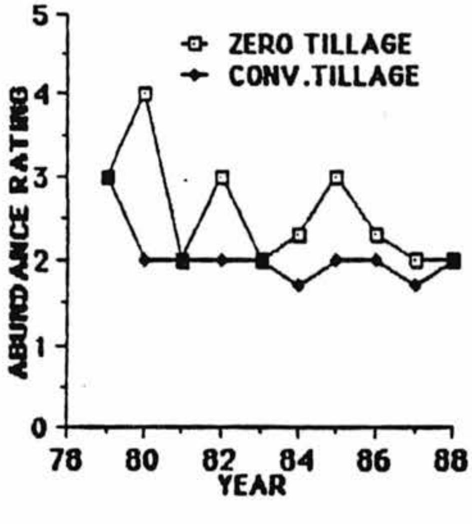

Fig.8 BROADLEAF ANNUALS (exc.stinkweed)

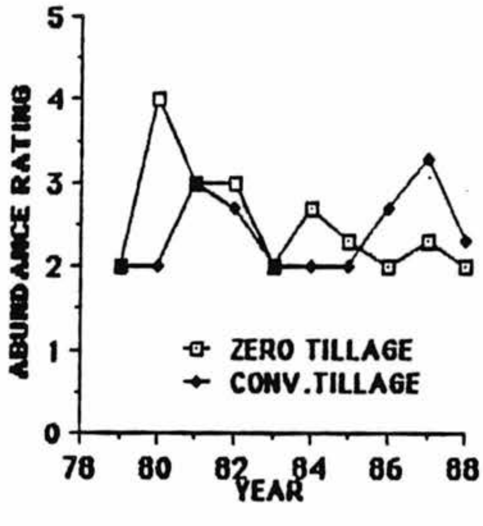

FIGURE 5 TO 8. ABUNDANCE RATINGS FOR SEVERAL WEED SPECIES UNDER ZERO AND CONVENTIONAL TILLAGE CONDITIONS.

conventional tillage (Table 4). An examination of data for the oilseeed crops and for wheat revealed that the oilseeds yielded less and wheat more under zero tillage in the continuous rotation. In the 3 year fallow rotation oilseed yields were similar for both tillage systems but wheat yields were higher for zero till.

Measurements made on levels of crop residue on the soil surface in 1988 (Table 5) showed consistently higher levels for zero till. In all cases zero till had at least double the amount of crop residue compared with the corresponding conventional tillage treatment. The residue levels with zero till were adequate to provide a very high degree of protection against erosion. By contrast in the conventional tillage system residue levels were very low for the oilseed on fallow treatment in the 3 year fallow rotation.

Table 4. Grain Yield of Crops Grown in 2 Rotation using Zero and Conventional Tillage practices. (Scott, Sask. 1979-88).

	tillage system	
rotation	zero	conventional
continuous crop		
- oilseed	1378	1501*
- wheat	1985	1753*
fallow-oilseed-wheat		
- oilseed	1308	1314
-wheat	1924	1836*
all crops	1672	1606*

* denotes significant differences between tillage systems (P=0.05)

Table 5. Levels of Surface Crop Residues (kg/ha) in 2 Rotations with Zero and Conventional Tillage (in July 1988 after 10 yr).

	tillage system	
rotation	zero	conventional
continuous crop	3150	1550
3 year fallow		
- fallow	4960	1290
- oilseed on fallow	2590	180
- wheat on stubble	2320	860

SUMMARY

Zero tillage crop production proved to be an effective means of enhancing soil moisture at the time of seeding. Particularly during the fallow period where moisture levels were 21mm higher than for tillage fallow,but also in the continuously cropped rotation. Why moisture levels were not increased on stubble in the three year fallow rotation remains unanswered but may be due to lower levels of surface residues.

Yields of zero till wheat in the continuously cropped rotation reflected the increased soil moisture levels,but yields of oilseeds did not,nor did oilseed yields in the 3-yr fallow rotationwith zero till.The inability of the oilseeds to produce higher yields under zero till was due to poorer weed control.Yields of wheat in the 3-yr fallow rotation were higher with zero till than conventional despite having similar soil moisture levels.

The results suggest that a major deterrent to more widespread acceptance of zero till production is the difficulty in achieving adequate weed control and the associated higher costs of weed control.However if adequate, affordable weed control can be achieved there is potential to enhance yields through more efficient use of moisture.WEED CONTROL IS THE KEY.

The amount of residue on the soil surface was always adequate to provide a high level of protection against erosion.